Extended Abstracts of the 22nd (1990 International) Conference on Solid State Devices and Materials, Sendai, 1990, pp. 239-242

Substrate-Dependent Characteristics of APCVD Oxide Using TEOS and Ozone

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Substrate-dependent characteristics of APCVD oxides using TEOS and O_3 have been investigated minutely in order to study the unique deposition mechanism. The deposition characteristics such as deposition rate and morphology depend on the top surface conditions of substrates to be just deposited, which is strongly enhanced with increasing the deposition temperature and O_3 concentration. This would be due to the interaction between TEOS oligomers and by-products generated by the reaction of TEOS oligomer and O radical on the film surface.

1. INTRODUCTION

Multilevel interconnection becomes an essential technology for VLSI devices because it actually determines the packing density as well as device performance, yield and reliability. One of its key technologies is a formation of interlayer dielectrics, which is required as follows:

(i) excellent step coverage properties and void free filling of high aspect-ratio gaps.

(ii) deposition at low temperature (<400℃) so as not to damage the underlying interconnects.

(iii) good planarization capability.

Recently, various CVD's using TEOS (tetraethylorthosilicate ; $Si(OC_2H_5)_4$) for silicon source instead of conventional silane (SiH_4) have been investigated extensively. As one potential solution to overcome aforesaid tasks, an atmospheric-pressure CVD (AP-TEOS) oxide using TEOS and ozone (O_3) has attracted much attention for its excellent step coverage with smooth flowing profile, which is achieved at 375℃ and high O_3 concentration [1,2,3]. Also, it has been reported that the deposition rates depend on substrate surface materials [3,4,5].

This paper presents an extensive study on substrate-dependent characteristics of AP-TEOS oxides in order to study the unique deposition mechanisms as well as to apply to VLSI devices.

2. EXPERIMENTAL PROCEDURES

An APCVD system shown in Fig.1 was used for the deposition experiment. TEOS is supplied by a temperature controlled bubbler with N_2, while O_3 is produced by an ozonizer with O_2. TEOS and O_3 are mixed

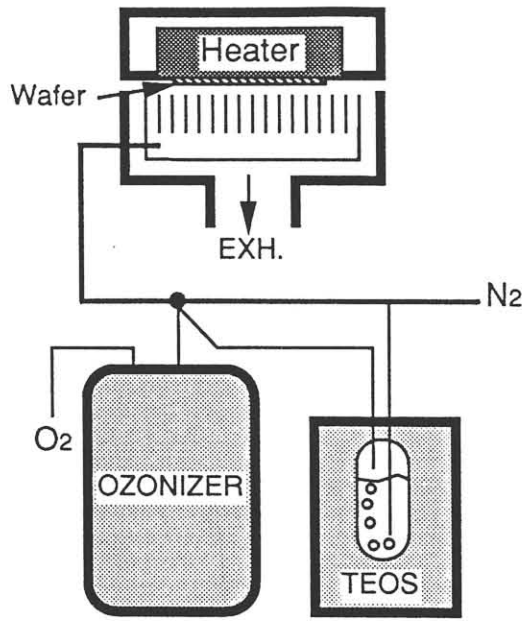

Fig.1 APCVD system using TEOS and O_3.

before being fed through a dispersion head to the substrate which is held face down on a heated susceptor by a vacuum chuck.

AP-TEOS oxides were deposited on various substrate materials and structures which are shown in Fig.2. The deposition temperature for this study was varied from 275℃ to 450℃, while O_3 concentration was varied from 0.5% to 5.0%.

The film thicknesses of AP-TEOS oxides were examined by optical measurement, and the surface morphologies and cross sectional views were observed by SEM.

3. RESULTS AND DISCUSSION

The dependence of the film thickness on deposition time is shown in Fig.3. AP-TEOS oxides were deposited on Si substrates and thermally grown oxides (th-SiO(A)), which were formed in O_2 and H_2 ambient, under the conditions that deposiiton temperature = 400℃, TEOS flow rate = 100 SCCM, O_2 flow rate=7.5SLM, and O_3/O_2 flow ratio = 5.0 %. Two deposition methods were used ; one is a single deposition and another is a repeated deposition. A single deposition means that oxide films are continuously deposited on each wafer for a certain time, and a repeated deposition means that they are deposited step by step on the same wafer. In the case of the single deposition, the deposition rate of AP-TEOS oxides on th-SiO(A) is smaller than that on Si substrate, while in the case of the repeated deposition, the deposition rates are independent on the substrate materials. These results indicate that this CVD process is controlled by surface reaction, and the growth kinetics displays the memory of the top surface of the substrate on which films are just being deposited. Also, it should be noted that the film growth starts with some delay time for all samples.

Figure 4 shows the ratio of the deposition rate on th-SiO(A) to that on Si substrate (R(th-SiO(A))/R(Si)) as a function of the deposition temperature and O_3 concentration. It is found that the ratio remarkably decreases with increasing the deposition temperature and O_3 concentration. High temperature and high O_3 concentration enhance the essential reaction, which could be considered as follows : In the gas phase, O_3 decomposes thermally to O_2 and O radical, which reacts TEOS (polymerization) to produce TEOS oligomers. These TEOS oligomers on the substrate surface are oxidized and dehydrated by the O radical to form oxides.

Substrate Materials

- bare Si
- Al
- BPSG
- thermally grown oxide formed in O_2 and H_2 ambient (th-SiO(A))
- thermally grown oxide formed in O_2 and HCl ambient (th-SiO(B))

Substrate Structures

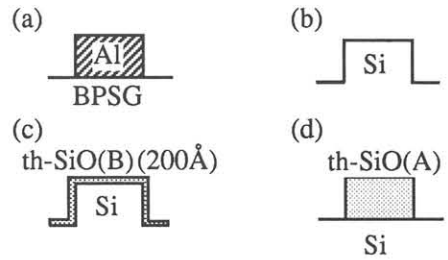

Fig.2 Substrate materials and structures used for this study.

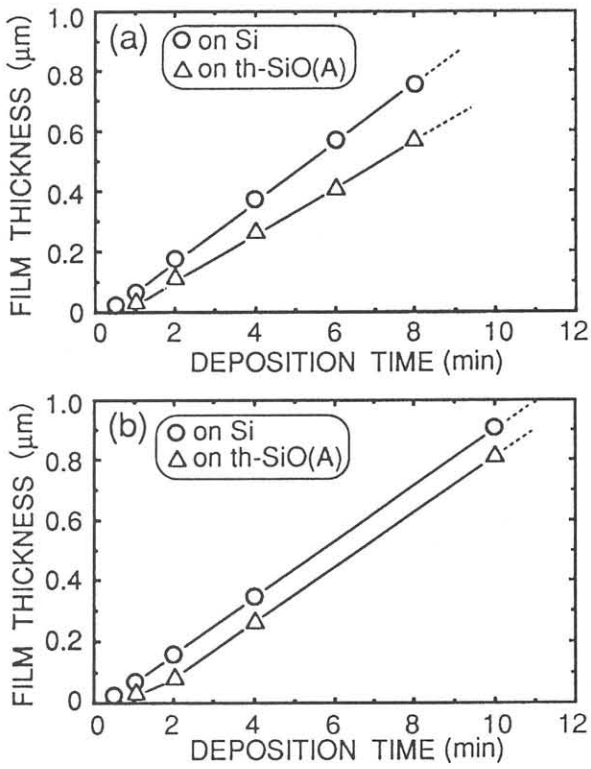

Fig.3 Film thickness of AP-TEOS oxide vs. deposition time on Si and th-SiO(A). Two deosiiton methods were used : (a) single deposiition and (b) repeated deposition.
(TEOS=100SCCM,O_2=7.5SLM,O_3/O_2=5%, at 400°C)

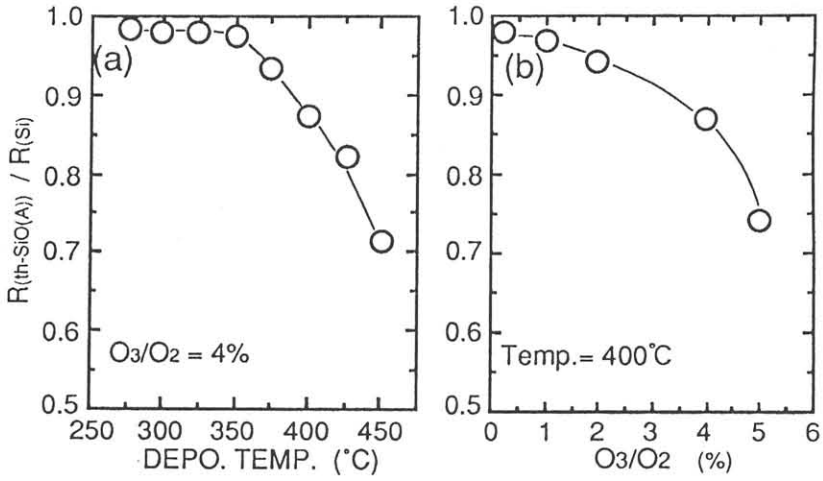

Fig.4 Deposition rate ratio ($R_{(th\text{-}SiO(A))}/R_{(Si)}$) vs. deposition conditions. (TEOS=100SCCM, O_2=7.5SLM)

The oxidization and dehydration generate such by-products as H_2O, C_2H_5OH and $(C_2H_5)_2O$ on the top surface of the film to be just deposited. The dependence of the deposition rate on substrate materials could be caused by the influence of the interaction between TEOS oligomers and by-products.

Figure 5 shows cross sectional SEM pictures of the step coverages on various substrate structures and materials. In the case of Al steps on BPSG and Si steps, the step coverage exhibits " smooth flowing profile" as deposited, which can be characterized by the decrease in film thickness at steps [3]. On th-SiO(B)(200Å), which were formed in O_2 and HCl ambient, the nucleations come into existence on the surface sites for an early stage of deposition, and they do not grow to be a continuous film. This abnormal deposition is due to the scarcity of the adsorption sites for TEOS oligomers on the top surface to be deposited. In the case of th-SiO(A) steps on Si substrate, the aspect ratio decreases with increasing the deposition time because the deposition rate on th-SiO(A) is smaller than that on Si substrate. This result is anticipated that a global planarization can perfectly be achieved by depositing a relatively thick film.

4. CONCLUSIONS

Substrate-dependent characteristics of APCVD oxide using TEOS and O_3 have been investigated minutely in order to study the unique deposition mechanism and to apply VLSI devices. Deposition characteristics of AP-TEOS oxides depend strongly on the characteristics of the top surface to be deposited. This is considered to be the influence of the interaction between TEOS oligomers and by-products such as H_2O, C_2H_5OH, $(C_2H_5)_2O$ etc. ; TEOS oligomers are produced by the reaction of TEOS and O radical in the gas phase, while by-products are generated by the reaction of TEOS oligomer and O radical on the film surface. And, these characteristics are proposed to realize a new "self-planarization" process by controlling the surface of VLSI devices.

ACKNOWLEDGMENTS

The authors wish to thank Drs. H.Komiya and T.Nakano for their continuous encouragements through this work.

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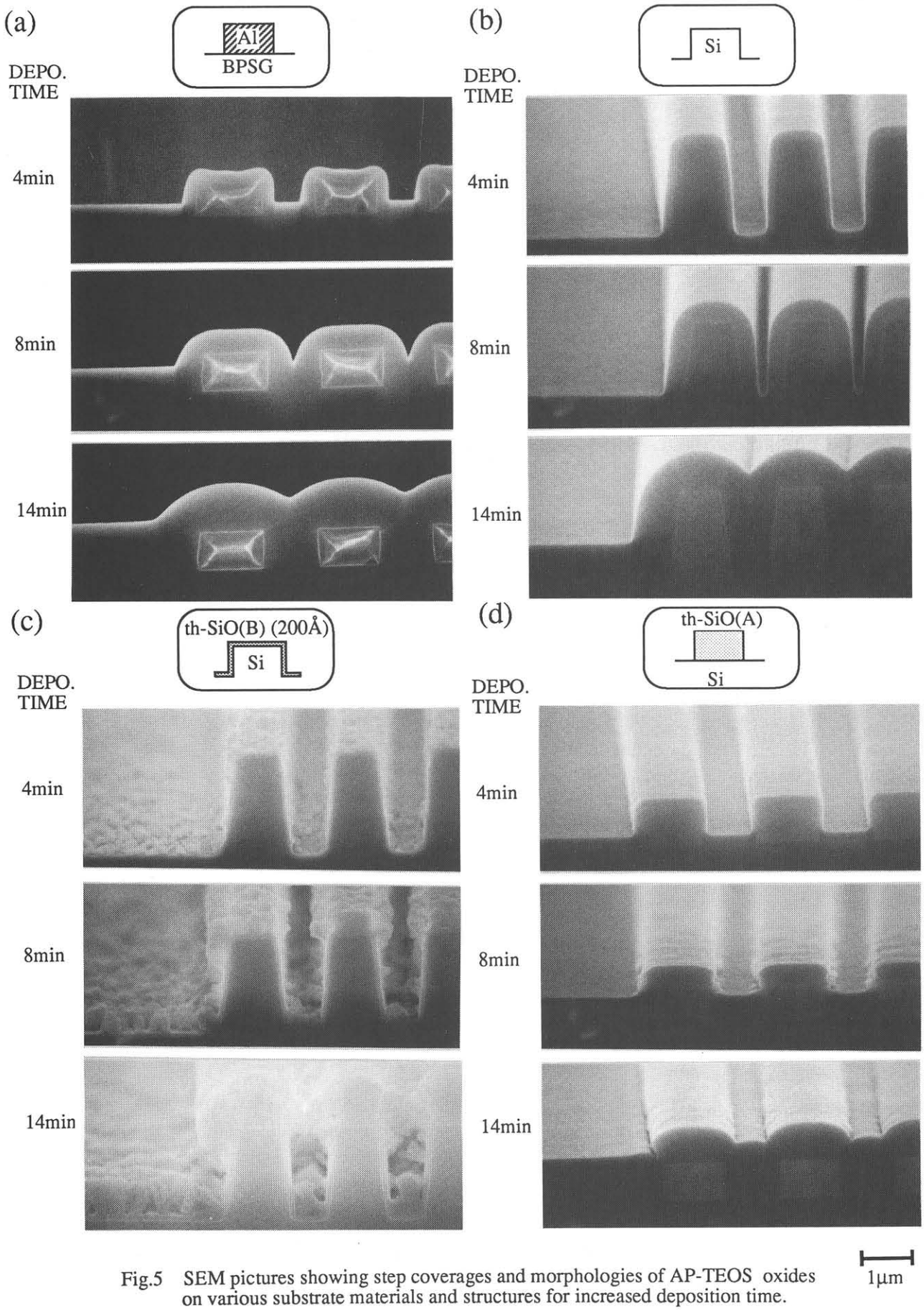

Fig.5 SEM pictures showing step coverages and morphologies of AP-TEOS oxides on various substrate materials and structures for increased deposition time.